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by

J.A. Kernan[1], J.E. Knipfel[2], W.L. Crowle[3], E.C. Coxworth[1] and A.E. Mair[1]

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ABSTRACT

A laboratory study to determine the effect of ammoniation on the ease of grinding of awned and non-awned chaff indicated that no effect was observed by either dry grinding (fragility) or wet grinding (mastication). Sheep trials on untreated, ammoniated uncovered, and ammoniated under plastic, Katepwa (non-awned) and Wakooma (rough-awned) chaffs indicated that ammoniation, especially under plastic, improved the digestibility and consumption of both chaffs. Steer trials on the same materials 1 year later were confounded by a possible reversal of the ammoniation reaction during the summer, and contamination with excessive dirt, indicated that Wakooma chaff ammoniated under a cover showed the most improvement and gave the best performance. The animal trials will be repeated.

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INTRODUCTION

During the past 10 years, many laboratory and digestibility studies have been conducted on ammoniated crop residues and low to medium quality hays. However, very few performance studies have been conducted to determine the value of ammoniated straw or chaff as the basis for a cow maintenance ration or a calf growing ration. It has been demonstrated that chaff from cereal crops may be a valuable ruminant feed from a nutritional standpoint. However, there have been no investigations regarding the economic value of chaff, both from nutritional and weed-tillage elimination standpoints.

In addition, while ammonia treatment of chaff has been shown to be beneficial from standpoints of increasing nutritive value and also destruction of seed viability, there are several unresolved problems in the ammoniation process, specifically whether stacks require plastic covering and/or the consequences of not covering stacks. A major deterrent to ammoniation has been the use of plastic covers, and if simpler methods could be applied, the ammoniation process would be more widely practiced.

Thirdly, with increasing incidence of awned varieties of cereals, the potential for use of this material as a livestock feed has increased, but the presence of awns renders chaff relatively unpalatable to animals. Our preliminary studies with sheep indicate that ammoniation renders chaff from rough-awned wheat cultivars, such as Norstar Winter Wheat or HY 320, much more acceptable to animals and the resulting increase in intake is very substantial. In subsequent feeding trials with beef cows there did not appear to be the same degree of reluctance to consume awned chaff in relation to non-awned chaff. These

observations suggest that there may be substantial differences between beef cattle and sheep in acceptance of chaff from awned cultivars, thus prejudicing the applicability of sheep intake/digestion data to cattle.

The present studies were undertaken to attempt to determine how ammoniation physically affected both the awned chaff and non-awned chaff, and to compare intakes, and digestibilities of both types of chaff untreated and ammoniated with and without a plastic cover, using wethers and steers. In addition, the nutritive values of the chaffs were assessed by means of a feeding trial with pregnant beef cows.

Laboratory study

MATERIALS AND METHODS

Awns

Twenty kg of Norwin winter wheat (rough-awned cultivar) was harvested by hand from a Crop Science plot on the Kernen Farm of the University of Saskatchewan in the fall of 1987. The material was dried in a forced air drier at 40°C and threshed through a stationary Hege combine at the Saskatoon Experimental Station of Agriculture Canada to yield 2 kg of awns. Four 100 g samples of these awns were treated with 3% anhydrous ammonia at 20% moisture and 20°C for three weeks. Representative samples of treated and untreated awns were submitted to the Feed Testing Laboratory (FTL) of the University of Saskatchewan for crude protein (CP) analysis (AOAC 1973) and duplicate samples were sent to the Swift Current Research Station of Agriculture Canada for in vitro organic matter digestibility (IVOMD) analysis (Troelsen 1970). The remainder of each sample was retained for fragility and mastication tests.

Chaff

Four replicates of each of several cereal cultivars were harvested from Agriculture Canada plots at the Saskatoon Experimental Station in the fall of 1987. The replicates were dried, 35 g of each were ammoniated and sub-samples were submitted for analysis as described for the Norwin winter wheat awns. The barley cultivars harvested were Bonanza, Scout, Harrington, Leduc, Ellice and Argyle. The wheat cultivars harvested were Roblin, Columbus, Neepawa, Leader, Sceptre, H^{V} 320, Katepwa, and Wakooma (durum). The remainder of each sample was retained for fragility and mastication tests.

Fragility Test

A fragility test was developed by Zorrilla-Rios et al. (1984) to attempt to determine why straws from different cultivars were digested in the rumen at different rates. The test was established to determine the relative ease that straws from different cultivars would break up when ground under specific conditions. Two g of straw was ground for 20 sec in a Moulinex 228.113 coffee grinder and sieved through 0.5 and 1 mm screens for 5 min. The weight of straw contained between the two sieves is expressed as a percentage of the total sample.

A sample of rough-awned chaff was treated with 3% anhydrous ammonia at 20°C and 20% moisture for 3 weeks. Six untreated and 6 ammoniated samples were tested to evaluate the fragility test.

Mastication Test

An artificial masticator was designed at the Swift Current Experimental Station of Agriculture Canada by Troelsen and Knipfel several

years ago. The mastication test has evolved to the point that 10 g of material emersed in a specified volume of water in a 1 l plastic beaker was ground between a set of gears for a specified time. The resulting mixture was wet screened through a series of screens, again for a specified time, and dried in an oven. The weight of sample trapped between screens was recorded.

RESULTS AND DISCUSSION

Nutritional Value of Cultivars and Awns

The analytical results confirm that barley chaff is of superior nutritional value than wheat chaff both before and after ammonia treatment, although wheat chaff responds better to ammonia treatment than does barley chaff (Table 1, Figs. 1, 2, 3, 4). Pure Norwin awns are inferior to both barley and wheat chaff in nutritional value but do respond well to ammonia treatment (Table 1). These results indicate that both ammoniated wheat and barley chaff should provide adequate CP and energy to over winter pregnant cows when supplemented with vitamins and minerals. Both protein and energy supplementation would be required for a calf growing ration.

Table 1 Effect of ammoniation on the crude protein content and digestibility of wheat and barley chaff

Cultivar	Untreated CP	Untreated ASH	Untreated IVOMD	Ammoniated CP	Ammoniated ASH	Ammoniated IVOMD
Barley						
Scout	5.3^{b}	12.0^{g}	48.7^{ab}	11.6^{a}	9.4^{cd}	61.9^{bc}
Bonanza	8.6^{f}	9.6^{abcd}	61.9^{g}	13.6^{d}	8.2^{a}	67.1^{ef}
Harrington	7.0^{d}	10.7^{def}	58.3^{f}	12.3^{ab}	9.0^{bc}	66.2^{e}
Leduc	8.3^{f}	9.4^{abc}	62.7^{g}	13.6^{d}	8.4^{ab}	67.1^{ef}
Ellice	6.8^{d}	11.1^{ef}	58.5^{f}	12.2^{ab}	10.4^{fg}	64.5^{de}
Argyle	7.9^{e}	10.6^{cdef}	59.2^{f}	13.8^{d}	8.2^{a}	69.0^{f}
Mean	7.3	10.6	58.2	12.9	8.9	66.0
Average Increase	-	-	-	5.5	-	7.8
Wheat						
Roblin	5.1^{ab}	10.9^{ef}	47.8^{a}	11.5^{a}	10.6^{fg}	59.6^{a}
Columbus	5.5^{b}	10.1^{bcde}	50.4^{c}	12.8^{bcd}	9.8^{de}	60.3^{ab}
Neepawa	5.8^{c}	8.7^{a}	51.1^{cd}	13.6^{d}	8.2^{a}	62.1^{bc}
Leader	5.5^{b}	9.2^{ab}	49.5^{bc}	12.5^{abc}	9.4^{cde}	59.2^{a}
Septre	5.7^{c}	10.8^{def}	54.5^{e}	12.3^{ab}	11.2^{h}	60.4^{ab}
HY 320	4.8^{a}	11.6^{f}	50.2^{c}	11.6^{a}	11.1^{gh}	59.1^{a}
Katepwa	5.8^{c}	9.5^{abcd}	50.3^{c}	13.4^{cd}	8.9^{bc}	64.0^{cd}
Wakooma	5.1^{ab}	10.4^{cdef}	52.0^{a}	12.3^{ab}	10.1^{ef}	59.7^{a}
Mean	5.4	10.2	50.7	12.5	9.9	60.6
Average Increase	-	-	-	7.1	-	9.8
Norwin Awns[1]	2.4	8.9	44.7	8.3	8.3	53.1
Significance of Cultivar Effect	<0.001	<0.05	<0.001	<0.10	<0.001	<0.001

1 not included in statistical analysis

means in the same column with the same letter are not significantly different ($p = 0.05$)

CP - crude protein

IVOMD - in vitro organic matter digestibility

Fig. 1. Effect of ammonia on OMD

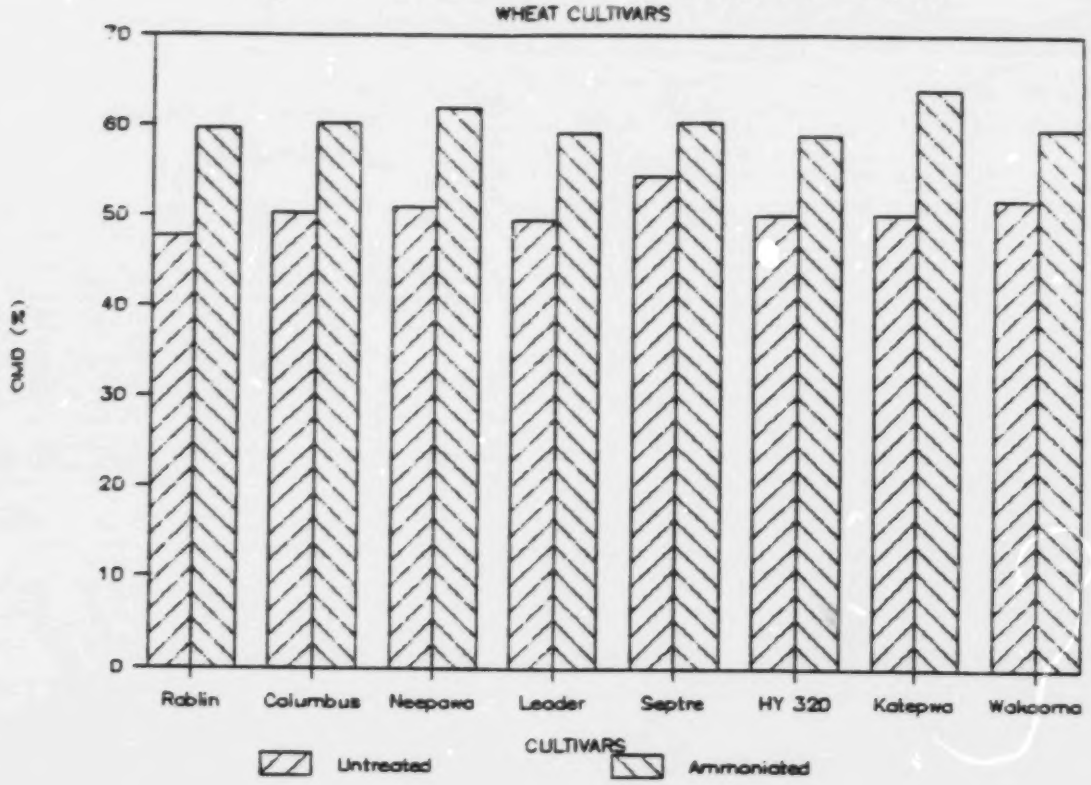


Fig. 2. Effect of ammonia on CP

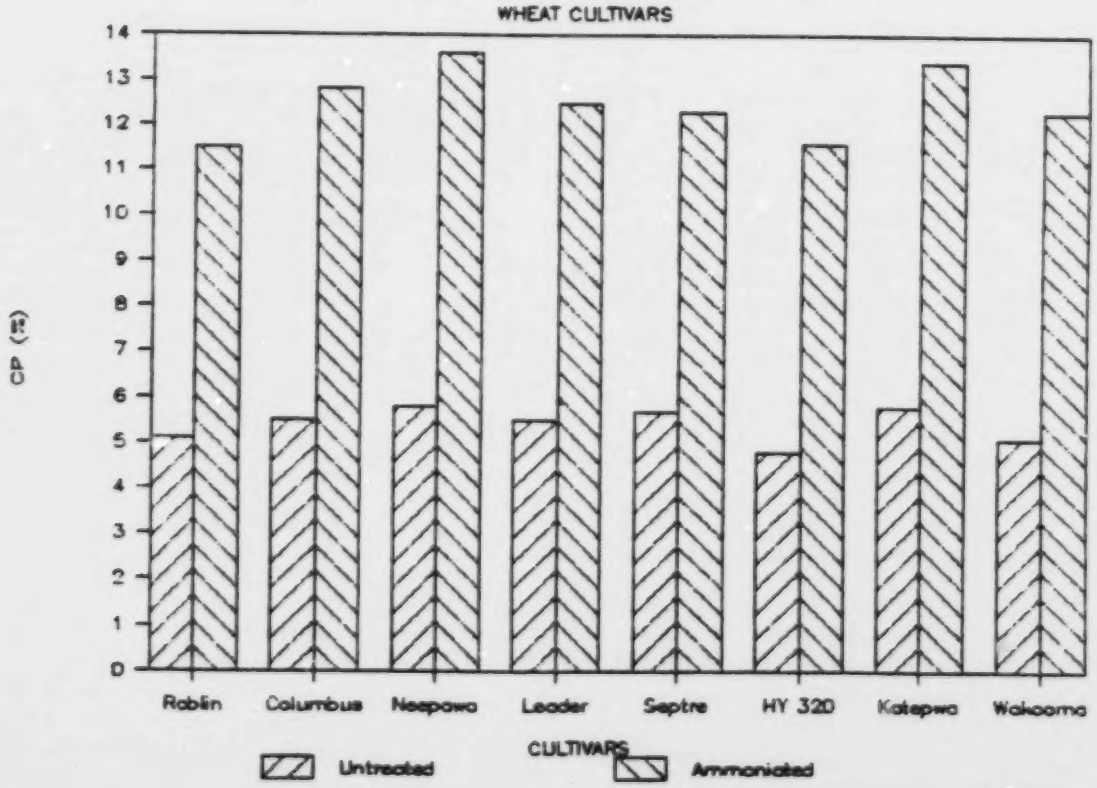


Fig. 3. Effect of ammonia on OMD

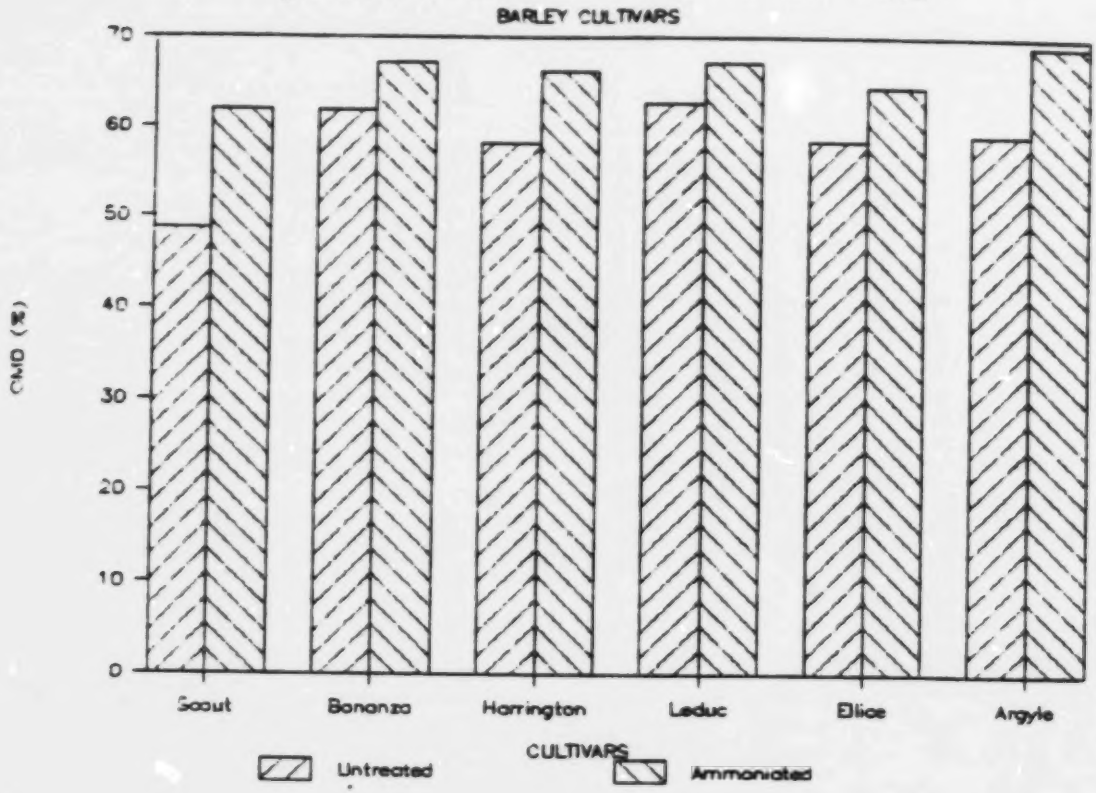
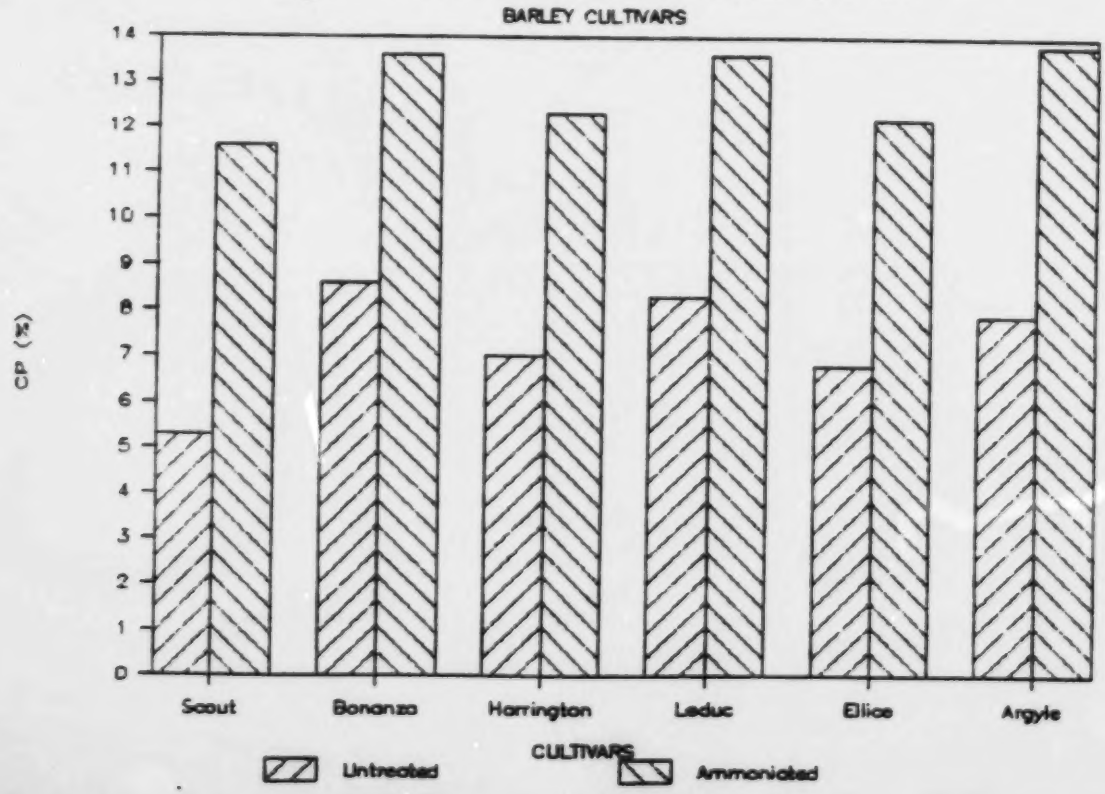


Fig. 4. Effect of ammonia on CP



Fragility Test

The samples prepared to evaluate the fragility test were run as specified by Zorrilla-Rios et al. (1984).

Table 2. Fragility test on untreated and ammoniated rough awned chaff at 8.8% moisture.

Treatment	Fragility (%)	Standard Deviation
Ammoniated	37.8	1.4
Untreated	39.8	3.4
Significance of Treatment Effect	NS	-

Based on these results the fragility test will not distinguish between untreated and ammoniated chaff. The variability within each treatment was too high and the difference between treatments too small to make the test useful.

Mastication Test

The results of the mastication test (Table 3) on untreated and ammoniated HY 320, Katepwa chaff, and Norwin awns does not appear to show any trend whatsoever. There does appear to be differences in mastication among the cultivars tested which remain somewhat consistent when comparing untreated vs ammoniated samples. Ammoniation does not appear to have much affect on the ability of this test to grind up wet samples.

Table 3. The effect of the artificial masticator on untreated and ammoniated HY 320 and Katepwa wheat chaff, and Norwin awns (Mean ratio - g per sieve/total recovery)

Cultivar Treatment	HY 320 Chaff		Katepwa Chaff		Norwin Awns	
	Unt	NH3	Unt	NH3	Unt	NH3
Sieve Size						
4	0.17	0.19	0.35	0.56	0.02	0.01
10	0.49	0.43	0.38	0.28	0.22	0.24
18	0.15	0.24	0.20	0.08	0.28	0.25
35	0.12	0.11	0.05	0.05	0.31	0.30
60	0.07	0.03	0.02	0.03	0.16	0.21
Mean Total Recovery (g)						
	7.87	7.78	7.96	7.88	8.12	7.93

The results of both the fragility test and the mastication test appear to indicate that ammonia treatment has little effect on the wet or dry grindability (fragility) of barley and wheat chaff and awns.

The settling of a straw stack and a pile of chaff following ammoniation suggests that the physical effect of ammoniation may be a softening rather than an increase in fragility of the chaff particles. A compressibility test will be devised and ammoniated and untreated chaff samples, at a consistent moisture content, will be tested for ease of compression during the second year of the animal trials.

Animal Trials

MATERIALS AND METHODS

Chaff

Chaff was collected from farmers fields following harvest, using the Rem chaff collection system. For Katepwa wheat chaff, the chaff piles were picked up from the stubble field using a John Deere forage

harvesting system. For the Wakooma durum wheat chaff, the piles were picked up with a front end loader equipped with forks and were loaded in grain trucks for movement to the Research Station. Each chaff was deposited in a stack on the ground and water was added to raise the moisture content to approximately 15%. The chaff piles were then divided with 1/3 of each total amount subjected to the following treatment: no additional treatment; addition of 3.5% anhydrous ammonia to the uncovered stack; or covering with 6 mil black plastic and ammoniating with 3.5% ammonia as described by Kernan and Knipfel (1981). The stacks were left for 6 weeks before beginning the animal experiments.

Sheep Digestibility Trial

Each chaff treatment was fed to 4 individually caged wethers in a randomized block design for 28 d, with feed intake determined daily for the duration of the test. Total fecal collection was undertaken for each wether for 7 d from day 21 to 28. Feed, refused feed, and feces were dried, ground and analyzed for organic matter (OM) and nitrogen (N) (AOAC 1973); energy by bomb calorimetry; cellulose (Crampton and Maynard 1938); neutral detergent fibre (NDF) and acid detergent fibre (ADF) (Goering and van Soest 1970). In vitro organic matter digestibilities (IVOMD) were determined by the method of Troelsen (1970). The data were analyzed by accepted analysis of variance procedures for randomized block designs (Steel and Torrie 1960).

Cow feeding Trial

Two pens of 4 pregnant Hereford cows were fed each chaff in a randomized block design for a 75 day period from 8 December 1986 to 22 February 1987. Brome hay was fed to 2 additional pens of 4 animals each. Feed intake for the pen was recorded daily for the duration of the test period. Refused feed was collected and sampled weekly. The cows were individually weighed at the beginning of the trial, on day 36 and at the conclusion of the test (day 75), with back fat measurements taken by ultrasonic probe at each weighing.

Steer Digestibility Trial

Each chaff treatment, as well as a good quality grass hay, was fed to 2 steers for a 21 d period in metabolism stalls with voluntary feed intake recorded daily. Prior to placement in the metabolism stalls each animal was fed the test diet for 21 d with 2 animals per pen. For the last 10 d of the metabolism stall feeding, 0.5% chromic oxide, Cr_2O_3, was fed to each steer, as a percentage of the intake in the form of pelleted barley containing 10% Cr_2O_3. Total fecal collections were taken for the final 5 d of the digestion trial. Samples of feed and refused feed, as well as feces were analyzed for dry matter (DM), OM, N, energy, NDF, ADF, and cellulose by procedures earlier described. Chromic oxide was determined in feeds and feces (Hill and Anderson 1958). Digestibilities were calculated using the Cr_2O_3 ratio technique (Harris 1970).

RESULTS AND DISCUSSION

Laboratory analyses undertaken at the time of the wether digestion trial (Table 4) suggested that Wakooma durum wheat chaff was nutritionally superior to Katepwa wheat chaff, in terms of both N and IVOMD.

Table 4. Composition of diets fed to wethers, cows and steers

	%OM	% IVOMD	%N	%NDF	%ADF	%Cellulose
For Wether Digestion						
Katepwa	88.4	36.1	0.84	70.1	42.7	36.9
Wakooma	84.8	46.6	1.0	62.8	35.8	32.8
Katepwa NH_3-U	88.6	42.9	1.1	71.4	42.9	37.6
Wakooma NH_3-U	86.1	49.7	1.32	68.0	39.8	36.6
Katepwa NH_3-C	88.1	47.5	1.34	68.5	42.5	37.0
Wakooma NH_3-C	85.2	54.7	1.56	63.5	40.2	34.8
Hay	92.1	51.0	1.26	65.3	39.0	34.5
For Steer Digestion						
Katepwa	86.9	-	0.88	67.7	43.8	36.8
Wakooma	81.7	-	0.74	63.5	41.4	35.0
Katepwa NH_3-U	86.4	-	0.97	69.3	42.4	36.1
Wakooma NH_3-U	73.8	-	0.52	63.4	36.8	31.2
Katepwa NH_3-C	88.2	-	0.81	72.2	45.7	38.1
Wakooma NH_3-C	85.6	-	1.03	66.6	41.6	36.2
Grassy Hay	91.3	-	1.31	68.6	39.1	34.3
For Cow Feeding						
Katepwa	89.1	54.2				
Wakooma	88.2	44.1				
Katepwa NH_3-U	90.7	46.9				
Wakooma NH_3-U	89.9	49.2				
Katepwa NH_3-C	87.9	40.8				
Wakooma NH_3-C	87.8	54.0				
Brome-alfalfa Hay	90.8	52.3				

U-uncovered
C-covered

In addition, ammoniation increased both N and IVOMD, while a further increase in these 2 nutritional parameters occurred when the chaff pile was covered with plastic (Table 4).

Analyses of samples taken approximately 1 year later at the time of undertaking the steer digestion trial showed considerable variation to those analyzed earlier, with N contents lower than for the previous analyses. These data may have indicated inadequate sampling procedures, changes in N with time after ammoniation, or non-uniformity in the chaff piles. There were, in addition, substantial differences in IVOMD between samples taken at the time of the sheep digestion trial and the cow feeding trial. Further study revealed that, particularly in the case of the Wakooma chaff, extensive contamination with soil had occurred, likely due to picking up the chaff piles from the field with the front end loader. This is evident (Table 4) in the relatively high ash content of Wakooma NH_3-U fed in the steer digestion trial. Also, there were many fecal samples extremely high in ash (40-50%), and refused feeds were similarly very high in soil content, with ash contents greater than 60% in several instances. The extent to which this inclusion of soil may have influenced digestibilities is unsure at this time, but further investigation of potential effects is warranted.

Digestibility coefficients determined with wethers indicated (Table 5) the enhancing effect of ammoniation upon organic matter digestibility (OMD), nitrogen digestibility (ND), and energy digestibility (ED), although the effects were not statistically significant in many instances. A similar observation ocurred when digestible nutrient contents (Table 3) are examined. The lack of statistical significance

Table 5. Digestibility coefficients for chaff treatments[1] as determined with wethers

Constituent	Brome	Diet Fed: Katepwa			Wakooma			Sx
		Unt[2]	NH_3 U[3]	NH_3 C[4]	Unt	NH_3 U	NH_3 C	
OMD	57.5^{ab}	48.3^{b}	53.3^{ab}	54.2^{ab}	52.4^{ab}	57.3^{ab}	62.4^{a}	2.2
ND	45.2	38.7	42.0	41.1	45.6	50.5	54.6	7.7
CelD	63.7^{abc}	58.3^{c}	59.8^{c}	63.5^{abc}	60.8^{bc}	69.0^{ab}	71.8^{a}	2.0
NDFD	60.9^{ab}	53.0^{b}	55.2^{b}	60.3^{ab}	59.1^{ab}	65.5^{a}	69.2^{a}	2.3
ADFD	59.9^{ab}	52.4^{b}	52.5^{b}	59.5^{ab}	57.1^{ab}	62.9^{a}	66.8^{a}	2.3
ED	53.0	47.2	50.0	50.8	49.0	53.2	55.1	2.4

1-Means with same or no superscript in same row not significantly different ($P<0.05$)
2-Untreated
3-Uncovered
4-Covered

may be due to high standard errors of estimate (Sx), which are suggested to result from variation in the feeds composition due to soil contamination. An additional benefit of covering chaff piles with plastic prior to ammoniation is apparent for both chaffs, (Table 4). Ammoniation increased the digestibility of the various fibre fractions (NDFD, ADFD, celD), while there was little effect upon ND. These data further confirm that ammoniation should not be considered primarily as a method of N supplementation, but rather as a means of improving energy availability. Intakes of various constituents (Table 7) emphasizes that ammoniation may improve both the intake of DN as well as energy related constituents. The covering of chaff piles with plastic appeared to improve the efficiency of the ammoniation reaction over that observed when non-covered chaff piles were ammoniated (Table 7).

Table 6. Digestible nutrient contents for chaff treatments[1] as determined with wethers

Constituent	Brome	Diet Fed: Katepwa			Wakooma			Sx
		Unt[2]	NH_3 U[3]	NH_3 C[4]	Unt	NH_3 U	NH_3 C	
DOM	49.8^{a}	35.1^{c}	38.8^{bc}	40.9^{abc}	39.4^{ab}	40.0^{ab}	47.4^{ab}	2.1
DN	0.60^{ab}	0.35^{b}	0.43^{b}	0.45^{b}	0.60^{ab}	0.70^{ab}	0.88^{a}	0.08
DCel	22.1^{b}	21.3^{bc}	19.8^{c}	23.8^{b}	22.3^{bc}	25.7^{ab}	28.4^{a}	0.87
DNDF	40.6^{bc}	37.7^{bc}	35.5^{c}	43.4^{ab}	40.8^{bc}	46.3^{ab}	49.1^{a}	1.72
DADF	24.1^{b}	22.8^{bc}	19.2^{c}	25.7^{ab}	24.3^{b}	25.6^{ab}	29.9^{a}	1.07
DE	2.30	1.95	1.95	2.08	2.02	2.10	2.15	0.10

[1]-Means with same or no superscript in same row not significantly different ($P<0.05$)
[2]-Untreated
[3]-Uncovered
[4]-Covered

In spite of the apparent nutritional superiority of Wakooma durum wheat chaff over that of Katepwa wheat chaff (Table 7), in the cow feeding trial (Table 8) Wakooma durum wheat chaff or the same chaff ammoniated but not covered gave weight losses when fed as the sole diet. The effect may be at least partially attributed to lower feed intakes (Table 8). Ammoniation did improve the nutritive values of the chaffs as evidenced by higher gains or less losses than for the untreated chaffs, and the additional nutritional benefit from covering the chaff piles was again obvious. In all groups there was a loss of back fat over the course of the study (Table 8), with the extent of losses in back fat apparently unrelated to weight gains or losses.

Table 7. Consumption of digestible constituents[1] of chaff treatments as determined with wethers

Constituent	Brome	Diet Fed: Katepwa			Wakooma			Sx
		Unt[2]	NH_3 U[3]	NH_3 C[4]	Unt	NH_3 U	NH_3 C	
CDOM	33.2^{ab}	18.5^{c}	22.4^{c}	26.3^{bc}	25.7^{bc}	26.1^{bc}	36.7^{a}	2.2
CDN	0.35^{b}	0.15^{c}	0.20^{bc}	0.28^{bc}	0.35^{b}	0.38^{ab}	0.55^{a}	0.04
CDCel	13.8^{ab}	9.2^{b}	9.5^{b}	13.0^{b}	13.1^{b}	12.6^{b}	17.9^{a}	1.0
CDNDF	25.4^{ab}	17.8^{b}	17.0^{b}	23.7^{ab}	23.6^{ab}	23.1^{ab}	30.9^{a}	1.9
CDADF	15.1^{ab}	9.8^{c}	9.2^{c}	14.1^{abc}	13.1^{bc}	13.8^{abc}	18.8^{a}	1.1
CDE	142.0^{a}	85.1^{b}	92.1^{b}	114.0^{ab}	105.2^{ab}	114.4^{ab}	134.7^{a}	8.46

1-Means with same or no superscript in same row not significantly different ($P<0.05$)
2-Untreated
3-Uncovered
4-Covered

Determination of digestibility of the various chaffs with steers (Table 9) suggested that ammoniation had little effect of the Katepwa chaff, but a marked improvement on the Wakooma chaff, particularly in energy and OM digestibilities. Associated with these increases were increases in digestibility of the fibre fractions (Table 9). No apparent explanation can be given for this discrepancy with the data of Table 5, but the time lag of 1 year between the 2 digestibility trials may have allowed reversal of the ammoniation effect, as has been suggested by other studies. However, it would be expected that both chaffs would decrease to preammoniation levels, if a simple reversal of the ammoniation reactions were involved.

Table 8. Performance of pregnant beef cows fed awned and non-awned chaff and the effect of ammoniation

Diet	Weight Gain		Feed Intake	Back Fat (mm)	
	kg	kg d^{-1}	kg d^{-1}	Initial	Final
Brome-alfalfa Hay	26.3	0.34	9.1	8.5	7.5
Katepwa Wheat Chaff	3.4	0.05	9.2	6.8	5.2
Wakooma Wheat Chaff	-15.5	-0.20	7.2	7.9	5.4
Katepwa-NH_3-U[1]	14.0	0.18	12.1	11.1	7.3
Katepwa-NH_3-C[2]	9.0	0.12	11.1	9.8	6.5
Wakooma-NH_3-U	-9.0	-0.11	8.1	9.9	6.6
Wakooma-NH_3-C	29.2	0.37	7.8	10.9	9.0

1-Uncovered
2-Covered

Table 9. Digestibility coefficients for chaff treatments as determined with steers

Constituent	Diet Fed						
	Grass Hay	Katepwa			Wakooma		
		Unt[1]	NH_3-U[2]	NH_3-C[3]	Unt	NH_3-U	NH_3-C
OMD	60.1	59.8	60.0	57.1	52.5	57.4	65.2
ND	46.6	44.6	47.6	40.1	37.5	42.3	43.5
CelD	69.1	69.0	69.7	67.4	64.9	71.5	73.7
NDFD	67.3	63.6	66.7	64.8	58.6	68.8	71.3
ADFD	63.5	63.4	64.7	62.8	59.8	54.7	69.7
ED	56.3	56.7	57.4	56.5	49.9	53.8	62.8

1-Untreated
2-Uncovered
3-Covered

While there was no apparent increase in DE due to ammoniation (Table 10), it is of interest that these DE values should be adequate to provide maintenance of a pregnant cow, and in the cow feeding trial the

Table 10. Digestible nutrient contents for chaff treatments as determined with steers

Constituent	Grass Hay	Diet Fed					
		Katepwa			Wakooma		
		Unt[1]	NH_3-U[2]	NH_3-C[3]	Unt	NH_3-U	NH_3-C
DOM	54.9	52.0	51.9	50.3	42.9	42.4	55.8
DN	0.61	0.39	0.47	0.32	0.28	0.22	0.45
DCel	23.7	25.4	25.2	25.7	22.7	22.3	26.7
DNDF	46.2	43.1	46.2	46.8	37.2	43.6	47.5
DADF	24.8	27.8	27.5	28.7	24.8	23.8	29.0
DE	2.42	2.24	2.25	2.29	2.09	1.77	2.44

1-Untreated
2-Uncovered
3-Covered

Katepwa chaffs all provided positive gains (Table 8). Conversely, both the Wakooma chaffs which resulted in weight losses of cows had the lowest DE contents observed. These data are, however, inconsistent with the intakes of DE (Table 11). Many studies have suggested maintenance DE requirements of approximately 125 Kcal $kg^{-0.75}$, which were achieved

Table 11. Consumption of digestible constituents of chaff treatments as determined with steers

Constituent	Diet Fed						
	Grass Hay	Katepwa			Wakooma		
		Unt[1]	NH_3-U[2]	NH_3-C[3]	Unt	NH_3-U	NH_3-C
CDOM	45.3	40.6	39.5	35.5	23.6	31.4	48.4
CDN	0.50	0.31	0.36	0.23	0.20	0.16	0.39
CDCel	19.7	19.8	19.1	18.2	11.3	16.5	23.2
CDNDF	38.2	33.7	35.2	33.0	26.7	32.2	41.2
CDADF	20.5	21.7	20.9	20.2	17.8	17.6	25.2
CDE	199.6	125.0	171.2	161.6	149.8	123.4	211.7

1-Untreated
2-Uncovered
3-Covered

by all diets fed in this study. However, in the case of the Wakooma durum chaff, either untreated or ammoniated and uncovered, DN intakes were lower than for the other diets and suggest that weight losses might have resulted from a combination of inadequate DN and DE intakes together.

There was considerable variation exhibited among animals and among the different studies undertaken, which likely masked real differences. A repeat of these studies with improved chaff collection procedures is necessary to fully elucidate the effects observed.

These studies have demonstrated the beneficial effect of ammoniation of wheat chaffs, both awned and non-awned. There was little indication that awned chaff was less readily accepted than the non-awned chaff, by either wethers or steers, in contrast to earlier studies. Covering chaff piles prior to ammoniation appears to offer an incremental benefit over that of ammoniation alone. The economic consequences of these procedures need to be further studied.

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